H11

APPENDIX

REPORT ON THE FEASIBILITY

OF

A 15,000 KILOWATT ELECTRIC POWER STATION

USING GEOTHERMAL HEAT SOURCES

AT

MAMMOTH AREA, MONO COUNTY, CALIFORNIA

PREPARED FOR

THE MAGMA-NATURAL STEAM POWER PROJECT

PREPARED BY

ROGERS ENGINEERING CO., INC.
16 BEALE STREET
SAN FRANCISCO 5, CALIFORNIA

JANUARY 1962

DISCLAIMER

JOB NO. 1771
JAN 62
RL

MAGMA-NATURAL STEAM POWER PROJECT

DOLLARS SHOWN IN 1000's

		DOUBLE FLASH CYCLE				CLOSED POWER FLUID CYCLE			
NO.	ITEM.	MATERIALS $	LABOR $	OVERHEAD & PROFIT $	TOTAL $	MATERIALS $	LABOR $	OVERHEAD & PROFIT $	TOTAL $
1	LAND & LAND RIGHTS	-	-	-	10.0	-	-	-	10.0
2	BORINGS & SOILS TESTS & SURVEY	-	-	-	10.0	-	-	-	10.0
3	STRUCTURES & IMPROVEMENTS	-	-	-		-	-	-	
	ACCESS ROADS & PARKING	-	-		10.0	-	-	-	10.0
	TEMPORARY BLDGS.	-			5.0	-			5.0
	FOUNDATIONS, BASES, EXCAVATION, BACKFILL	3.6	5.4	2.4	11.4	4.0	6.0	2.5	12.5
	STRUCTURES, INCL.	41.5	20.1	16.4	78.0	45.2	25.8	14.0	85.0
	LIGHT & PLUMBING	-	-	-	-			-	-
	CRANE (MANUAL)	5.9	0.5	0.1	6.5	5.6	0.5	0.1	6.2
	TURB. GEN. PEDESTAL	3.5	6.5	2.5	12.5	3.5	6.5	2.5	12.5
	FENCING	-	-	-	7.5	-	-	-	7.5
4	FLASH TANK	14.6	0.3	0.1	15.0	4.5	0.4	0.1	5.0
5	TURBINE-GENERATOR ⊗	847.0	50.0	13.0	910.0	670.0	45.0	11.7	726.7
	LUBE OIL SYSTEM	4.3	2.1	1.6	8.0	2.8	1.2	1.0	5.0
6	CONDENSER (S) ⊗	90.0	2.0	0.5	92.5	201.0	2.3	0.6	203.9
	EXHAUST DUCT ⊗	34.0	3.0	0.8	37.8	-	-	-	-
	CIR. WTR. PUMPS & MOTORS ⊗	41.5	2.0	0.5	44.0	57.0	1.5	0.4	58.9
	CIR. WTR. PIPING & VALVES	14.7	9.0	6.3	30.0	19.3	11.7	9.0	40.0
	GAS REMOVAL EQUIP. ⊗	20.0	1.5	0.4	21.9	0.4	0.5	0.1	1.0
7	HEATERS, BOILER & S. HTR. ⊗	—	—	—	—	225.0	5.6	1.4	232.0
8	BOILER FEED PUMP ⊗	—	-	-	-	53.0	3.0	0.8	56.8
9	CONDENSATE PUMP ⊗	—	—	—	-	27.3	0.9	0.3	28.5
10	PUMP-DOWN EQUIP. ⊗	—	—	—	—	20.9	0.2	0.1	21.2
11	ENGR'G. BY VENDOR	—	—	—	—	—	-	-	15.0
12	COOLING TOWER ⊗	—	—	—	121.7	-	-	—	231.0
13	COOLING TOWER BASIN	5.5	10.0	3.5	19.0	11.0	20.0	7.0	38.0
14	POWER PIPING	42.0	26.0	17.0	85.0	101.4	62.3	42.5	206.2
15	ELEC. EQUIP. & WIRING ⊗	175.0	43.0	16.0	234.0	175.4	43.5	14.8	233.7
16	INSTRUMENTS & CONTROLS	7.0	6.0	2.0	15.0	55.0	13.7	3.5	72.2
17	DRIP PUMPS & MOTORS	1.2	0.4	0.4	2.0	-	-	-	-
18	MISC (SHOP, TOOLS, LOCKERS, LAB, COMMUNICATIONS, ETC)	10.0	2.0	1.0	13.0	10.0	2.0	1.0	13.0
19	SUB-TOTALS	1,361.3	189.8	84.5	1799.8	1687.3	252.6	113.4	2341.8
20	CONTINGENCIES - 5%	12.00			90.0				117.1
21	TOTAL DIRECT COST				1,889.8				2,458.9
22	INTEREST DURING CONSTRUCTION - 3½%				66.1				87.1
23	POWER FLUID INVENTORY				--				60.0
24	ENGINEERING SERVICES - 7½%				141.7				184.4
25	TOTAL ESTIMATED COST				2,097.5				2,790.4

SH. No 2
4/4/63
N. [illegible]

POTENTIAL GEOTHERMAL POWER DEVELOPMENTS

LOCATION	GEOTHERMAL WELLS DRILLED	TESTED OUTPUT	REMARKS	ELEC. UTIL. CO. SERVING AREA
I STEAMBOAT, NEVADA	6 wells	Test not run yet - appear to have strong flow and heat	some calciting	Sierra Pacific Power Co.
II BRADY, NEVADA	5 wells	Test not run yet - appear to have strong flow and heat	some calciting	Sierra Pacific Power Co.
III BEOWAWE, NEVADA	4 wells	Tests run on 4 wells - 3 wells tested good, strong flow, good heat, no indication of salt.	slight silication	Nevada Power Co. also Sierra Pacific Power Co.
IV MAMMOTH, CALIFORNIA	6 wells	Tests run on 4 wells - One well tested good, 3 wells calcited. One well not productive. One new well drilled since tests were run - appears very good.	some calciting	California Elec. Power Co.
V IMPERIAL VALLEY, CALIFORNIA	Sportsman #1	Test run - hot well and strong flow, very salty	Well bore too small for good test of area.	Imperial Irrig. District
	I.I.D. #1	Test run - hot well and very strong flow - heavy brine		
VI MEXICALI, B.CFA, MEXICO	#1A	No test run, but well head temp. measured at 291°F. Strong flow, very slight salt		Comision Federal de Electricidad
VII WABUSKA, NEVADA	1 well	No test run - strong flow, but water temperature not to high (Approx. 140°F.).	Large deposits of Sodium Sulphate in this area.	Sierra Pacific Power Co.
VIII AMEDEE SPRINGS, CALIFORNIA	1 well 1 being drilled	No test		Pacific Gas & Elec. Co.

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4/4/62
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POTENTIAL GEOTHERMAL POWER DEVELOPMENTS

COMPANY AND LOCATION	TOTAL ENERGY SALES IN 1000 KILOWATT HOURS				
	1956	1957	1958	1959	1960
SIERRA PACIFIC POWER COMPANY RENO, NEVADA	388,273	412,306	449,220	517,229	599,215
Serves the west central section of Nevada		6.3% increase	9.0% increase	15.1% increase	15.7% increase
NEVADA POWER COMPANY LAS VEGAS, NEVADA	550,428	671,567	682,292	709,604	836,655
Serves the southern and northeast section of Nevada		22.0% increase	1.6% increase	4.0% increase	18.0% increase
CALIFORNIA ELECTRIC POWER COMPANY SAN BERNARDINO, CALIFORNIA	1,221,735	1,403,658	1,474,777	1,678,465	1,804,141
Serves inland southern California		14.9% increase	0.8% increase	13.8% increase	7.5% increase

Sierra Pacific Power Company — 1960

SYSTEM PEAK LOAD	127,190 KW.
GENERATING CAPACITY	27,350 KW.

Nevada Power Company — 1960

TOTAL ENERGY SALES	836,655,000 KW. HRS.
COMPANY GENERATION	663,395,000 KW. HRS.
GENERATING CAPACITY	290,000 KW.

California Electric Power Company — 1960

TOTAL ENERGY SALES	2,007,256,000 KW. HRS.
COMPANY GENERATION	1,862,248,000 KW. HRS.
GENERATING CAPACITY	331,000 KW. (ESTIM.)

IMPERIAL IRRIGATION DISTRICT
EL CENTRO, CALIFORNIA

Serves the Imperial Valley in southern California

AVERAGE ANNUAL POWER PROD. & USE

El Centro Plant (Thermal)	130,000,000 KW. HRS.	@ 15 mils/KWH.
HYDRO Plants (4)	250,000,000 " "	" 3.4 mils/KWH.
Purchased Power (Limited)	270,000,000 " "	" 4 mils/KWH.
Average Use	650,000,000 " "	" 5.9 mils/KWH.
Sales to other Utilities	175,000,000 " "	" 8.1 mils/KWH.
Sales to consumers	400,000,000 " "	" 1.85¢/KWH.

Note: Talk with Middleton
+ IR 3 ~~Oct~~ 62

$14^{\underline{00}}$/Hr Moore, Power,

$11^{\underline{00}}$/Hr Lerqquist, etc

Hal & R Wagne

For work on Casa Diabl

CABEEN FILE

Rogers
Daniels/Power
Howe
Ingall

Rogers Engineering Co., Inc.

Lejardi/Acctg.
File: P161-5
File: 1778
File: 1778-1
File: 1771

MEMORANDUM

TO: H. Rogers, Jr./Statler-Hilton, Los Angeles February 27, 1962

FROM: J. P. Lejardi/San Francisco

SUBJECT: 1. Low Cost Housing Project, #1778 and 1778-1
2. Magma Power, #1771

1. Low Cost Housing Project

You will find enclosed copies of the invoices from RECo to RICORP for 1778 and 1778-1 thru February 24, 1962. The total of these invoices amounts to $13,649.90. A memorandum to Cabeen International that you wanted is also enclosed showing the breakdown of direct and indirect costs.

2. Magma Power

You were asking about the due date of the $20,000 due from Magma Power so I am enclosing a copy of McCabe's letter indicating his understanding as to when payment is due. Hope we could receive a partial payment on the $12,000, it would certainly help. Incidentally, McCabe received our final report on January 23, 1962.

JPL

JPL:gc
Encls./as stated above

Rogers (2)
Daniels
Howe
[illegible]

MAGMA POWER CO.

631 SOUTH WITMER STREET
LOS ANGELES 17, CALIFORNIA
HUBBARD 3-2283

September 25, 1961

Rogers Engineering Co., Inc.
16 Beale Street
San Francisco, California

File: Contract #1771

Attn: Mr. H. Rogers

Gentlemen:

We are in receipt of your letter of the 21st instant outlining the financial terms and conditions under which you are undertaking the preparation of the feasibility report of the Casa Diablo power plant. I do not think the terms and conditions expressed in your letter cover adequately the agreement mutually arrived at under date of 15 September. Your letter is completely vacant on the subject of when the $20,000.00 of out of pocket expense is to be reimbursed to you by us.

The following understanding, I believe, encompasses our agreement. Within ninety days after the report proves the plant is not feasible or the financing for same does not materialize, we will pay you the sum of $12,000.00. The balance of $8,000.00 of the total of $20,000.00 agreed on will be paid by us at some future date when we have funds available for such payment but within a maximum period of two years.

If this letter as to its terms and conditions is agreeable to you, you may consider our agreement finished and proceed immediately with all due vigor on the feasibility report.

Yours very truly,

B. C. MC CABE, President

BCM/ra
cc: R.T.Burnham
cc: H.W.Falk
cc: W.M.Middleton

McCabe acknowledged receipt of final report on Jan, 23, 1962.

RECEIVED
SEP 26 1961
Rogers Engineering Co., Inc.
SAN FRANCISCO

APPENDIX

REPORT ON THE FEASIBILITY

OF

A 15,000 KILOWATT ELECTRIC POWER STATION

USING GEOTHERMAL HEAT SOURCES

AT

MAMMOTH AREA, MONO COUNTY, CALIFORNIA

PREPARED FOR

THE MAGMA-NATURAL STEAM POWER PROJECT

COPY NO. 29A

PREPARED BY

ROGERS ENGINEERING CO., INC.
16 BEALE STREET
SAN FRANCISCO 5, CALIFORNIA

JANUARY 1962

RECo 1771

APPENDIX

TABLE OF CONTENTS

SECTION 1.

CONSTRUCTION COST ESTIMATE BREAKDOWN

The cost estimates for the two types of geothermal electric generating plants, which are the subject of this report, have been prepared using manufacturer's estimates for major equipment items rather than definite quotations. These undoubtedly have a margin for possible refinements in the final specifications. Other items of the cost estimates reflect the recent experience of the Rogers Engineering Co., Inc. It is felt that the costs can be kept within these figures. In addition, a standard contingency item has been added, as shown, to cover the possibility of more fundamental changes in design, escalation, unforeseeables, and the like.

It is assumed, in making these estimates, that the major plant equipment would be purchased, to minimize overheads, directly by the owners or his engineers rather than through the general contractor.

The breakdown has been arranged to fit the standard system of capital accounts, which has been adopted by the Federal Power Commission and most state commissions. This would facilitate negotiations with a utility if this should ever prove desirable.

Costs In Thousands Of Dollars

Acct. No.		Double Flash Cycle: Materials	Labor	Contractor's Overhead & Profit	Totals	Closed Power Fluid Cycle: Materials	Labor	Contractor's Overhead & Profit	Totals
311	Structures and Improvements								
	Land and Land Rights				10.0				10.0
	Borings and Soils Tests				10.0				10.0
	Access Roads				10.0				10.0
	Fencing	4.0	2.0	1.5	7.5	4.0	2.0	1.5	7.5
	Foundations, Bases, Excavation and Backfill	3.6	5.4	2.4	11.4	4.0	6.0	2.5	12.5
	Power House Bldg. including Lighting and Plumbing	41.5	20.1	16.4	78.0	45.2	25.8	14.0	85.0
	Crane (Manual)	5.9	0.5	0.1	6.5	5.6	0.5	0.1	6.2
	Total 311	55.0	28.0	20.4	133.4	58.8	34.3	18.1	141.2
312	Boiler Plant Equipment								
	Flash Tank	14.6	0.3	0.1	15.0	4.5	0.4	0.1	5.0
	Heaters, Boiler & Superheater	-	-	-	-	229.0	5.6	1.4	236.0
	Boiler Feed Pump	-	-	-	-	53.0	3.0	0.8	56.8
	Power Piping	42.0	26.0	17.0	85.0	101.4	62.3	42.5	206.2
	Total 312	56.6	26.3	17.1	100.0	387.9	71.3	44.8	504.0
314	Turbine Generator Units								
	Condensing System								
	Condenser	90.0	2.0	0.5	92.5	204.0	2.3	0.6	206.9
	Exhaust Duct	34.0	3.0	0.8	37.8	-	-	-	-
	Cir. Water Pumps and Motors	41.5	2.0	0.5	44.0	52.0	1.5	0.4	53.9
	Cir. Water Piping and Valves	14.7	9.0	6.3	30.0	19.3	11.7	9.0	40.0
	Gas Removal Equipment	20.0	1.5	0.4	21.9	0.4	0.5	0.1	1.0
	Cooling Tower (Delivered & Erected)	-	-	-	121.7	-	-	-	231.0
	Cooling Tower Basin	5.5	10.0	3.5	19.0	11.0	20.0	7.0	38.0
	Condensate Pump	-	-	-	-	27.3	0.9	0.3	28.5
	Turbine-generator Pedestal	3.5	6.5	2.5	12.5	3.5	6.5	2.5	12.5
	Lube-oil System	4.3	2.1	1.6	8.0	2.8	1.2	1.0	5.0
	Instruments and Controls	7.0	6.0	2.0	15.0	55.0	13.7	3.7	72.4
	Turbine-generator	847.0	50.0	13.0	910.0	678.0	45.0	11.7	734.7
	Drip Pumps and Motors	1.2	0.4	0.4	2.0	-	-	-	-
	Total 314	1068.7	92.5	31.5	1314.4	1053.3	103.3	36.3	1423.9

(Costs In Thousands of Dollars)

			Double Flash Cycle				Closed Power Fluid Cycle			
Acct. No.			Materials	Labor	Contractor's Overhead & Profit	Totals	Materials	Labor	Contractor's Overhead & Profit	Totals
315	Accessory Electric Equipment									
		Total 315	175.0	43.0	16.0	234.0	175.4	43.5	14.8	233.7
370	Misc. Auxiliary Equipment									
	Shop, tools, lockers, laboratory, communication equipment, etc.		10.0	2.0	1.0	13.0	10.0	2.0	1.0	13.0
	Pump down and storage equipment		-	-	-	-	20.9	0.2	0.1	21.2
	Power Fluid Inventory		-	-	-	-	-	-	-	60.0
		Total 370	10.0	2.0	1.0	13.0	30.9	2.2	1.1	94.2
395	Misc. Construction Expenses									
	Engineering and Drafting		-	-	-	143.0	-	-	-	185.0
	Temporary Structures		3.0	1.0	1.0	5.0	3.0	1.0	1.0	5.0
	Interest during construction		-	-	-	66.1	-	-	-	87.1
		Total 395	3.0	1.0	1.0	214.1	3.0	1.0	1.0	277.1
	Sum of Sub-Totals		1368.3	192.8	87.0	2008.9*	1709.3	255.6	116.1	2674.1*
	Contingencies					90.0				117.0
	GRAND TOTAL					2098.9				2791.1
	For Cost Estimate, Use					2100.0				2800.0

*Includes items not distributed to breakdown columns.

SECTION 2.

OPERATING COST ESTIMATE BREAKDOWN

It is difficult to make an accurate forecast of the cost of operation for a plant of this type in its proposed location. It will depend upon the type of men available and their union affiliations, if any. Assuming it is an independent plant operated by a separate corporation, the annual requirements might be as follows:

Operation		
Superintendent	1 @ 9,000	$9,000
Shift Operators	4 @ 6,000	24,000
Operating Supplies		7,000
	Total	$40,000
Maintenance		
Labor, parts, tools and supplies		30,000
Total Operation and Maintenance		$70,000
Administration		20,000
	Grand Total	$90,000

Administration includes corporation officer's salaries, clerical and bookkeeping help, cost of director's meetings, office supplies, cost of working capital and similar items. This item is included in the tabulation more as a matter of record than for its absolute value, which Rogers Engineering Co., Inc. has no way of knowing accurately.

The estimate for the cost of operating labor is thought to be on the outside. If the plant were to be owned by a utility, all three items (operation, maintenance, and administration) would probably be greatly reduced. The costs would be fused with their own and the plant would be made automatic, eliminating nearly all the operating labor.

Even if owned by a separate corporation, part of this gain perhaps could be realized by arranging for an operator and a maintenance man to live near-by and have the necessary alarms extended into each house for quick response to trouble. The savings in larbor are, in such an arrangement, partly offset by the additional cost of the required automation.

SECTION 3.

HEAT CYCLE DATA FOR A 15,000 KW GEOTHERMAL UNIT

This table presents, in detail, the data used in and resulting from the heat cycle calculations for the cycles compared in this report. Note that there are two points in common for both cycles: the temperature of the well water in the ground, and the net output. All other data have been adjusted and made compatible between these two. Where two figures appear for certain items of the two flash steam cycle they refer to the two sections of the steam turbine.

Abbreviations used in this table are as follows:

^{o}F	= degrees Fahrenheit
#/hr	= pounds per hour
BTU/#	= British Thermal Units per pound
psi	= Pounds per square inch
psia	= Pounds per square inch absolute
In Hg	= Inches of Mercury
M	= One thousand
MM	= One million
#/c.f.	= Pounds per cubic foot
d P	= differential pressure
ft	= feet
gpm	= gallons per minute

ROGERS ENGINEERING CO., INC.

ENGINEERS

CALCULATION SHEET

SUBJECT HEAT CYCLE DATA 15,000 KW Geothermal Unit	MADE BY Moore	DATE Jan. '62	JOB NO. 1771
	CHECKED BY Power	DATE Jan. '62	SHEET NO. 1

		Closed Cycle Refrigerant 12	Double Flash Steam
Well temperature in ground	°F	350	350
Well water quantity	M#/hr	2176	2495
Enthalpy first separator	BTU/#	321.6	321.6
Temperature first separator	°F	281	281
Pressure first separator	psia	50	50
Flash in first separator	M#/hr	168	193.0
Enthalpy-steam from 1st separator	BTU/#	1174.1	1174.1
Water from 1st separator	M#/hr	2008	2302
Enthalpy-water from 1st separator	BTU/#	250.1	250.1
Temperature 2nd separator	°F	-	202
Pressure - 2nd separator	psia	-	12.0
Flash in 2nd separator	M#/hr	-	188.0
Enthalpy of flash - 2nd separator	BTU/#	-	1146.6
Water from 2nd separator	M#/hr	-	2114
Enthalpy of water from 2nd Separator	BTU/#	-	170.0
Steam to Non-condensables ejector	M#/hr	-	9.8
Power fluid	M#/hr	6100	183.2/188.0
Temperature Power Fluid	°F	265	281/202
Pressure Power Fluid	psia	600	50/12
Enthalpy Power Fluid	BTU/#	100.8	1174.1/1146.6
Condensing temperature	°F	119-100	101
Condensing pressure	psia	132	0.98=2."Hg

ROGERS ENGINEERING CO., INC.

ENGINEERS

CALCULATION SHEET

SUBJECT HEAT CYCLE DATA 15,000 KW Geothermal Unit	MADE BY Moore	DATE Jan. '62	JOB NO. 1771
	CHECKED BY Power	DATE Jan. '62	SHEET NO. 2

		Closed Cycle Refrigerant 12	Double Flash Steam
Enthalpy after isoentropic expansion	BTU/#	89.3	1070.5/966.0
Heat available	BTU/#	11.5	103.6/152.0
Turbine only efficiency	%	90	80.9/73.6
Heat converted to work	BTU/#	10.37	84.0/111.8
Heat converted to work	MMBTU/hr	63.3	56.9
Turbine shaft power - Gross	KW	18575	16700
Power at generator terminals	KW	16096	15800
Enthalpy exhaust	BTU/#	90.43	1006
Exhaust flow	M#/hr	6100	371.2

Auxiliary Power

Condensate flow	M#/hr	6100	-
Evaporator pressure	psia	600	-
Condenser pressure	psia	132	-
d P	psi	468	-
Add for friction & controls	psi	76	-
Total d P	psi	544	-
Equiv. head	ft	995	-
Fluid horsepower	HP	3064	-
Power for b.f. Pump from shaft	KW	2280	-

ROGERS ENGINEERING CO., INC.

ENGINEERS

CALCULATION SHEET

SUBJECT HEAT CYCLE DATA 15,000 KW Geothermal Unit	MADE BY Moore	DATE Jan. '62	JOB NO. 1771
	CHECKED BY Power	DATE Jan. '62	SHEET NO. 3

		Closed Cycle Refrigerant 12	Double Flash Steam
Circulating water flow	gpm	52500	34500
Motor input to N.C. Gas Pump	KW	-	20
Motor input to Water Pumps	KW	496	478
Motor input to Fans	KW	320	282
Motor input to Condensate Pump	KW	280	-
Total auxiliary power	KW	1096	800
Gross generation	KW	16096	15800
Net	KW	15000	15000

Heat to Condenser

Heat input to turbine	MMBTU/hr	614.9	430.3
Heat removed by turbine	MMBTU/hr	63.3	56.9
Heat left in exhaust	MMBTU/hr	551.6	373.4
Enthalpy of exhaust	BTU/#	90.43	1006
Enthalpy of condensate	BTU/#	31.1	69
Difference	BTU/#	59.3	937
Heat rejected	MMBTU/hr	361	346

ROGERS ENGINEERING CO., INC.

ENGINEERS

CALCULATION SHEET

SUBJECT HEAT CYCLE DATA 15,000 KW Geothermal Unit	MADE BY Moore	DATE Jan. '62	JOB NO. 1771
	CHECKED BY Power	DATE Jan. '62	SHEET NO. 4

		Closed Cycle Refrigerant 12	Double Flash Steam
Enthalpy-flash tank water discard	BTU/#	130.5	170
Temperature-flash tank water discard	°F	162	202
Work/# well water (net)	BTU/#	23.6	20.5
Weight well water per net Kwhr.	#/kw-hr.	145.0	166.2

SECTION 4.

PROPOSED WELL TEST PROGRAM

A. Purpose

The purpose of this test program is to investigate, test, and verify the quantity and quality of geothermal energy available from existing wells in the Mammoth area for the proposed 15,000 kilowatt power station, to investigate the potential of the geothermal field for additional development, and to establish the most satisfactory method, or combination of methods, for well effluent disposal.

B. Summary

All proven geothermal fields used for electric power production are associated with a volcanic heat source, a long term water supply for hot water and/or steam production, and a subsurface formation to trap the heat.

Wells drilled into the geothermal fields near Mammoth, California, have been flow-tested for about two weeks. Geological and physical observations substantiate the existence of a heat source, consisting of high temperature water. Analyses of the water show large amounts of alkali chloride, calcium bicarbonate, carbonic acid, boron, fluoride, arsenic, and silica. If allowed to flash and produce steam and water, these wells have a tendency to become plugged with calcium carbonate (calcite). The subsurface formation and long term water supply source have not yet been completely defined.

Use of this energy source for power production will require additional information. Data needed include: well production rates, longevity indication relative to rate of flow restriction by "calciting", analyses for chemical components in the water, thermodynamic properties of the hot well water, and analyses for noncondensable gases in the flashed steam. Evaluation of such data is necessary for: (1) predictions of cost and maintenance necessary to obtain a steady energy output, (2) specifications of material and size of plant components, and (3) design of effluent water disposal facilities.

During the limited flow tests used to prove the wells, the water produced was disposed of in the adjacent stream (Mammoth Creek). The resulting change in steam turbidity was noted and several water samples analyzed. Various government and public agencies expressed concern over these conditions to the Lahontan Regional Water Pollution Control Board. The Board then made known by resolution, the water temperature, turbidity and total mineral content which would be acceptable for addition to Mammoth Creek. In order to re-initiate well tests, various means of handling effluent water, during the tests, were discussed with the Board engineer in December. A plan, shown on Plate 4, appeared acceptable for the proposed test program, and was submitted in January 1962. Board action is still pending.

C. Recommendations

In view of the known and unknown limitations which may be imposed on effluent water disposal into Mammoth Creek, it appears desirable to proceed with the test program which proposes water re-injection into the producing formation. Successful re-injection and development of underground circulation should not require Board approval.

Proof of this method of water disposal would allow obtaining the data required to establish well production longevity (described in Phase 2).

Should re-injection be unsuccessful, a procedure developed as a result of Pollution Board action (similar to Phase 1C), should be used to obtain the necessary data.

In all of these tests trained personnel must supervise the field operations.

D. Detailed Description of Proposed Test Phases

This program is designed to obtain the additional data required to confirm the existing wells' continuous energy production capability, to determine criteria for power plant components specification and effluent water disposal facilities design.

Phase 1.

Tests on Wells 1 through 4, would consist of recording well head pressures, temperatures, and flows. The flow test equipment would be that utilized at other well sites, modified and augmented for this program; to enable measuring the steam flow, composition, temperature, pressure, and quality. In addition, the hot water would be separated, its flow measured, and its chemical content determined. This phase is further described depending on the method of water disposal as follows:

Phase 1A. Test flow of either well, No. 1 and/or 2 with re-injection of water into Well No. 3.

Phase 1B. Test flow of Well No. 4 with re-injection of water into Well No. 3.

Phase 1C. Test flow of Well No. 4 with water disposal via cooling ponds and recording weir into Mammoth Creek.

The well effluent water entering Mammoth Creek should be cooled and aerated. Water flow through at least six long channels separated by one foot high wooden baffles is planned. Cement compacted earth would be used at the turning corners and flow channels to prevent silt pickup. A weir of standard design will allow check of water flow, and along with water analysis be used to monitor the chemical quantities as requested by the Los Angeles Department of Water and Power.

A key plan of the area is attached as Plate 4.

Phase 2.

This phase would include a follow-up of Phase 1 with well tests extended over a 6-8 week period. Production decline, as caused by bore plugging (calciting), would be recorded. The cleanout schedule required for continuity of energy production would be developed, or the effectiveness of deposit prevention by chemical treatment would be determined.

Phase 3.

This phase is dependent on the results of the initial tests, and is further described as follows:

3A. This study would include assembling geological data, exploratory well data and/or heat flow profiles to enable satisfactory development of the heat energy required for the proposed 15 MW power plant.

3B. This study would include photogeological, geological, geochemical and hydrothermal surveys of the adjacent areas in order to establish a reasonably accurate measurement of heat flow possibilities for large scale power development. Final work would require some exploratory well drilling and assembly of a detailed formal report. This type of program would depend on the growth of a large power demand in this isolated area and would not appear warranted at this time. No estimate has been made of costs for Phase 3A or 3B.

E. Estimated Field Work Schedule and Cost

The estimates presented here have been developed to give the order of magnitude of the work and cost required for the program described in Phase 1. Continuity of the test program through the various sections in Phase 1 was assumed. By assigning a dollar value to the field labor, total estimated field costs can be obtained. Engineering supervision to obtain and analyze data, and report on the test program is not included. However, it is essential that qualified personnel be assigned to follow the test program and this cost must be considered.

Phase 1A. Test flow Well 1 or 2, re-injection to Well 3. Schedule: material delivery 2 weeks, field construction 2-3 weeks requiring approximately 200 manhours. Materials, analyses, equipment rentals and minimum design engineering, cost estimate - $2,000.

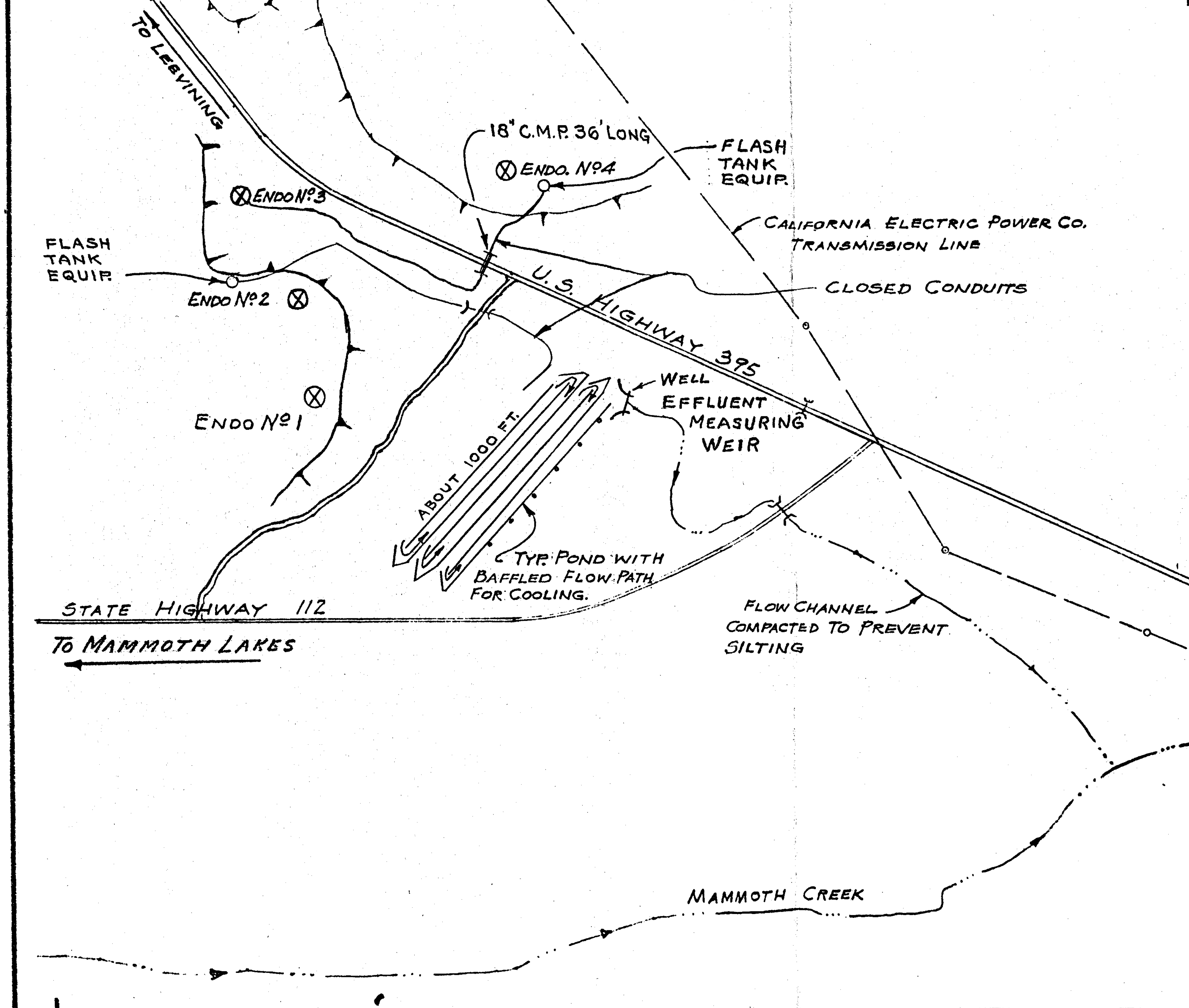
Phase 1B. Follow-up above work, test flow Well 4, re-injection to Well 3. Schedule: Lead time 2 days, field construction 2 weeks requiring approximately 240 manhours. Materials, analyses and equipment rentals, cost estimate - $1,000.

Phase 1C. Additional revisions, to test flow Well 4, with water disposal via cooling ponds into Mammoth Creek. Schedule: material delivery and field construction 3-4 weeks, requiring approximately 600 manhours. Materials, analyses and engineering design, cost estimate - $3,000.

F. Equipment Modification for Test Program

The bulk of the test equipment for measuring flashed steam and separated hot water is available. The modifications and new additions for the proposed test program are shown in Plates 4 and 5, attached. New material required has been cost estimated, and the detailed listing, including probable supplier is available on request. In addition, a field procedure manual and well log sheet are available to obtain and log the required data.

PLATE 4

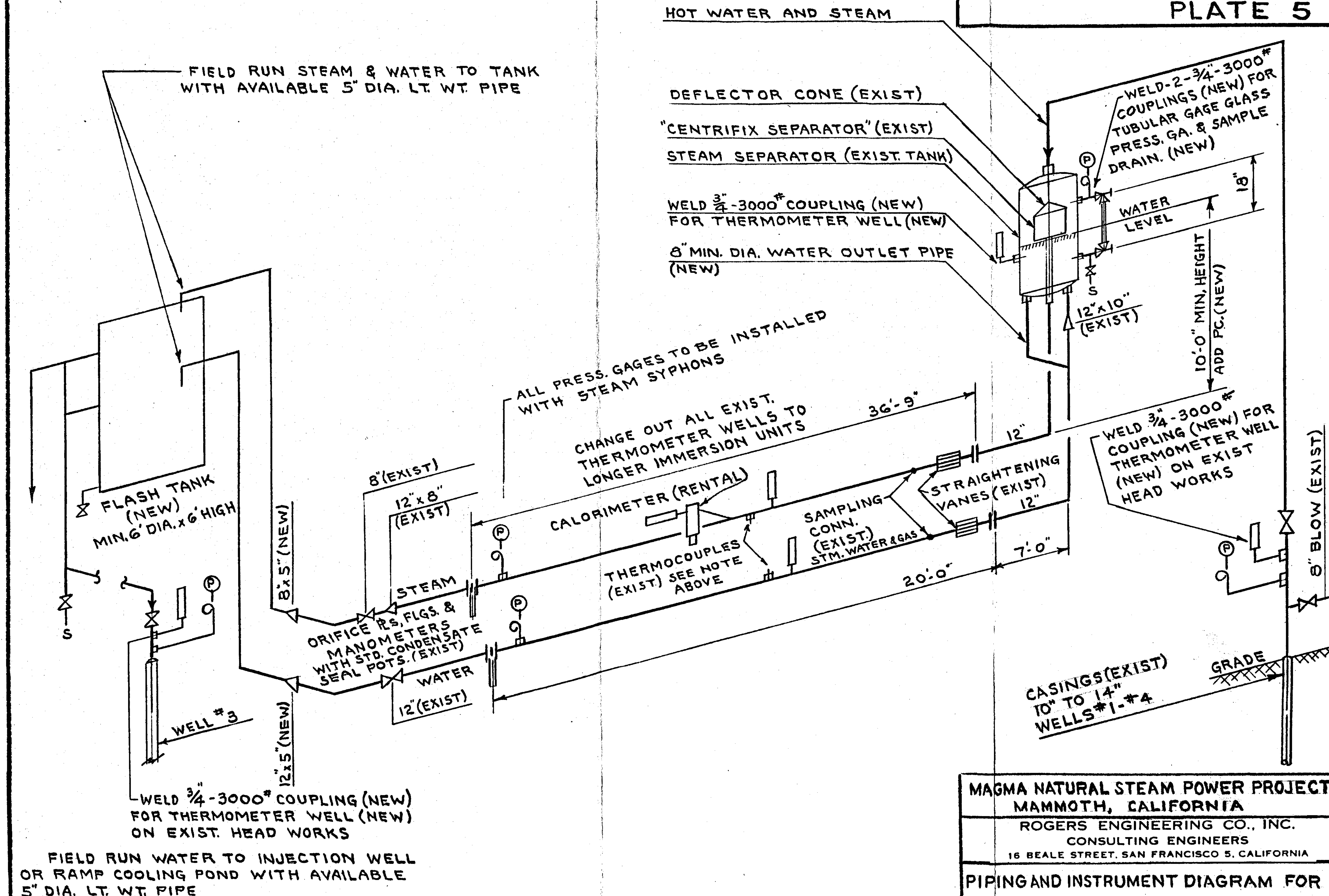


MAGMA-NATURAL STEAM POWER PROJECT
MAMMOTH, CALIFORNIA

ROGERS ENGINEERING CO., INC.
CONSULTING ENGINEERS
16 BEALE STREET, SAN FRANCISCO 5, CALIFORNIA

KEY PLAN

PLATE 4



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PIPING AND INSTRUMENT DIAGRAM FOR FLOW TESTS OF GEOTHERMAL WELLS

PLATE 5

SECTION 5.

DISCUSSION OF CHEMICAL MEANS FOR MINIMIZING OR REMOVING CARBONATE DEPOSITS IN GEOTHERMAL WELLS

A. Introduction

Commercial use of geothermal heat energy requires physical development of wells drilled into dry steam or hot water producing formations. Dry steam wells require little further maintenance to realize steady energy flow. In certain hot water wells subsurface carbonate deposits can be expected, requiring scheduled maintenance to insure usable energy flow. A review of available information has been made to compare methods of maintaining steady high rate energy output from these types of wells by chemical means. Cost estimates have been prepared for preventative treatment and deposit removal.

This discussion is general and is intended to provide background data on the problem. Additional studies should be made before specific recommendations are made.

B. Conclusions

1. Deposit formation rate is difficult to predict. Amount of deposit that can be tolerated before cleaning is required is a function of well flow, casing size, pressure drop allowable, and physical characteristics of deposit formation and water calcium content. Scaling appears in that section of the casing where flashing occurs. Using the existing wells at the Mammoth area as a base, a ton of material might accumulate before cleaning is required.

2. Deposits in hot water wells should be minimized by use of known scale prevention chemicals such as sodium tripolyphosphate or sodium hexametaphosphate.

3. Removal of existing deposits is possible using sulfamic or inhibited hydrochloric acid. The cost is high and it may take a long time. It appears that drilling out deposits would be less costly, take less time and assure removal.

4. Prevention of deposits using chemicals at the rates used in water treatment applications, if successful, appears less costly than acid dissolving or drilling out of existing deposits. Preliminary estimates, using wells at Mammoth area as a base, indicate chemical prevention cost of approximately \$100/well/month, acid dissolving cost of upwards of \$1,000 per cleanout, and drilling out cost of \$500 to \$700 per cleanout.

5. If chemical prevention of deposits is not successful, air injection, water injection or seeding of wells for deposit prevention/or control should be considered. Costs of these alternatives should be less than acid dissolving or drilling out of existing deposits.

C. General Recommendations

A test program should be initiated using chemical treatment for deposit prevention in the Mammoth wells. This program would determine the efficiency and effectiveness of chemicals in the dosages used for developing cost estimates. This program should run concurrently with well production tests.

It is recommended that well cleanouts by drilling, or acid dissolving be controlled by trained personnel to establish cost data, obtain samples for analysis and estimate deposit volume.

D. General Discussion

1. Introduction: The following summarizes material abstracted from articles by Donald E. White, U.S. Geological Survey; Gunner Bovarsson, State Elec. Auth., Reykjavik, Iceland: and examination of geothermal water analyses reported by these and other authors:

(a) High temperature geothermal areas are caused by magmatic heat.

(b) Dry steam areas occur where a heat source is fed by a limited water supply. The dry steam non-condensable gases are usually acidic; and if the steam is saturated, condensate of low chloride content is normal.

(c) Based on chemical and isotopic analysis, the steam or hot water in geothermal systems originates largely from a surface water source.

(d) Wet steam or hot water areas are characterized by water high in alkali chloride content. The subsurface structure accounting for this condition envisions heat from the deep hot magma vaporizing alkali chlorides. These high temperature vapors condense in an upper circulating water zone, and the hot water reacts further with the rock minerals and becomes saturated with calcium, boron and silica.

These conclusions seem to be agreed upon by most authorities.

2. Formation of Well and Spring Deposits: Release of undiluted geothermal hot water accompanied by reduction in either pressure or temperature will result in subsurface or surface spring deposits. From geothermal high alkali chloride content water systems, two major chemical types are possible:

(a) A basic silicate may be expected due to temperature effect if the undiluted hot water contains more than 350 ppm SiO_2 (silica). This type is not expected at Mammoth.

(b) A basic carbonate may be expected due to pressure effect (CO_2 release) if the undiluted hot water contains calcium above a few ppm.

3. Basic Carbonate Deposits: Calcium carbonate deposits usually occur as the result of a shift in the chemical equilibrium in the calcium-bicarbonate-carbonate system due to a loss of CO_2, as follows:

$$\underset{\text{(soluble)}}{\text{Calcium Bicarbonate}} \rightleftharpoons \underset{\substack{\text{(Insoluble)} \\ \text{(Calcite)}}}{\text{Calcium Carbonate}} + \text{Water} + \underset{\text{(gas)}}{CO_2}$$

Since this reaction is reversible, the closing in of a calcited well can be of some diagnostic value. With the well closed off the calcite deposit will slowly redissolve. When the well is re-opened, the test flow may approach original rates. Examination of known calcited wells reveals that deposits occur in an area termed the "flash zone". Apparently in this zone of steam formation with temperature and pressure reduction, the greatest change in CO_2 release also occurs. As a result, this is where calcium super-saturates and grows on the surface exposed at this point in the well.

Prevention of calcite deposit requires modification of the flash zone by physical or chemical means. The following are suggested for further studies:

(a) Chemical treatment with sodium hexametaphosphate or sodium tripolyphosphate to sequester the calcium and delay scaling.

(b) Injection of air into the well to lengthen the flash zone and possibly bring it to the well surface. This would be workable only with a closed cycle power turbine and separate hot water heat exchangers.

(c) Pumping a small flow of well head water back down to a deep well jet to obtain lift and prevent development of the flash zone until the water reaches the surface.

(d) Injection of a sludge of fine-sized calcite particles into the well as crystal seeds. The calcite would be expected to grow on these fine seeds and come out of the well by velocity lift.

(e) Keeping the casing surface clean using ultrasonic vibrations.

E. Cost Estimates for Chemical Deposit Prevention and Removal

Rough estimates of chemical costs for prevention and removal of well deposits follow: Costs include freight to Mammoth. Chemical supplier is shown in parentheses.

(a) Prevention Treatment (Well Flow 400 M lb/hr)

(1) Sodium Tripolyphosphate @ 2 ppm (Moberg, Los Angeles) — $120/well/month

(2) Sodium Tripolyphosphate @ 2 ppm (Maas Chemical - Stauffer, Los Angeles) — $60/well/month

(b) Removal (2000 pounds Calcite)

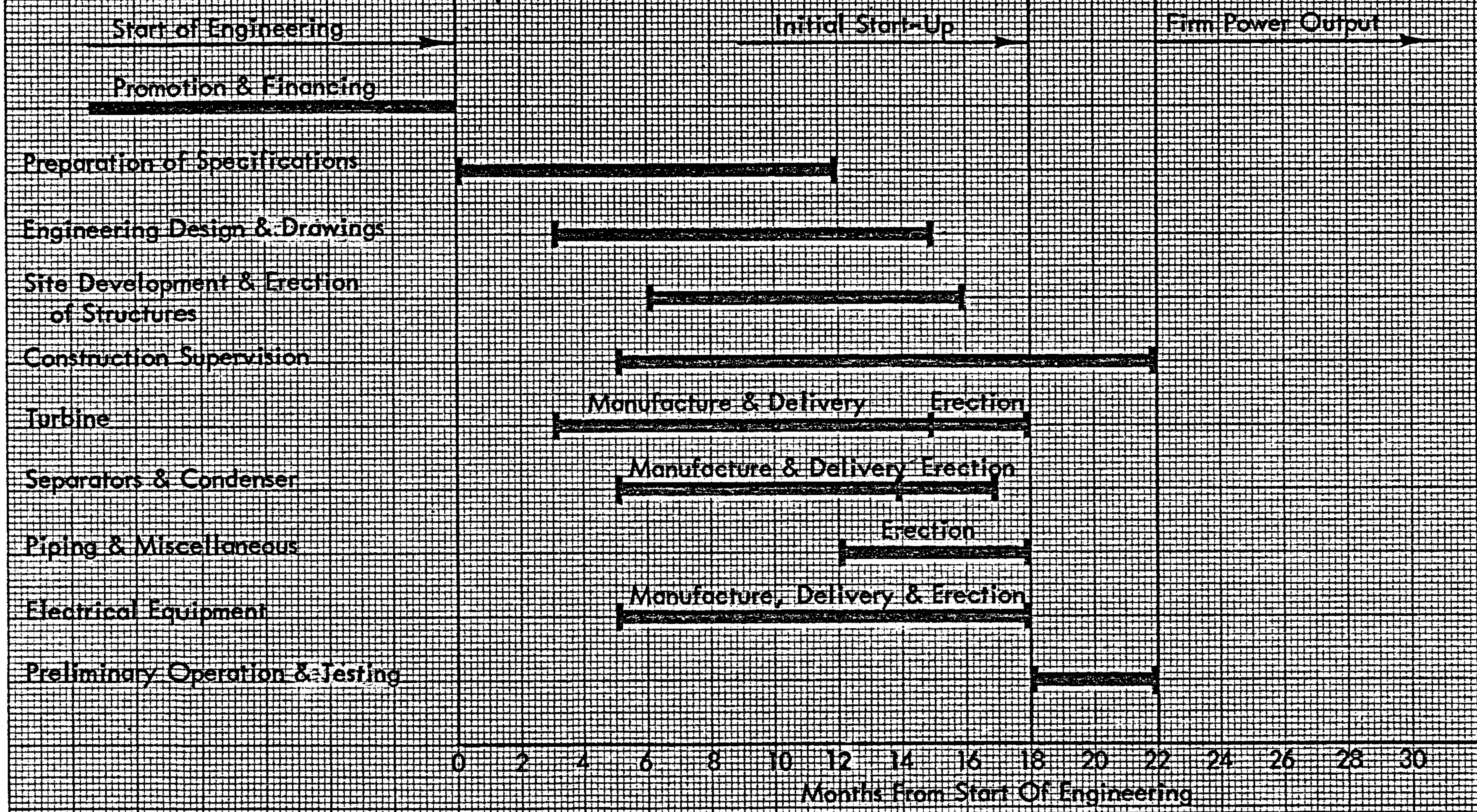
(1) Sulfamic Acid, 4600 lb (Braun, Knetch & Heiman) with Rodine 107 Inhibitor, 70 lb (American Paint & Chemical, Niles) — $1100/cleanout

(2) Oakite 32, 58 Carboys (Oakite, San Francisco) — $1200/cleanout

SECTION 6.

CONSTRUCTION SCHEDULES

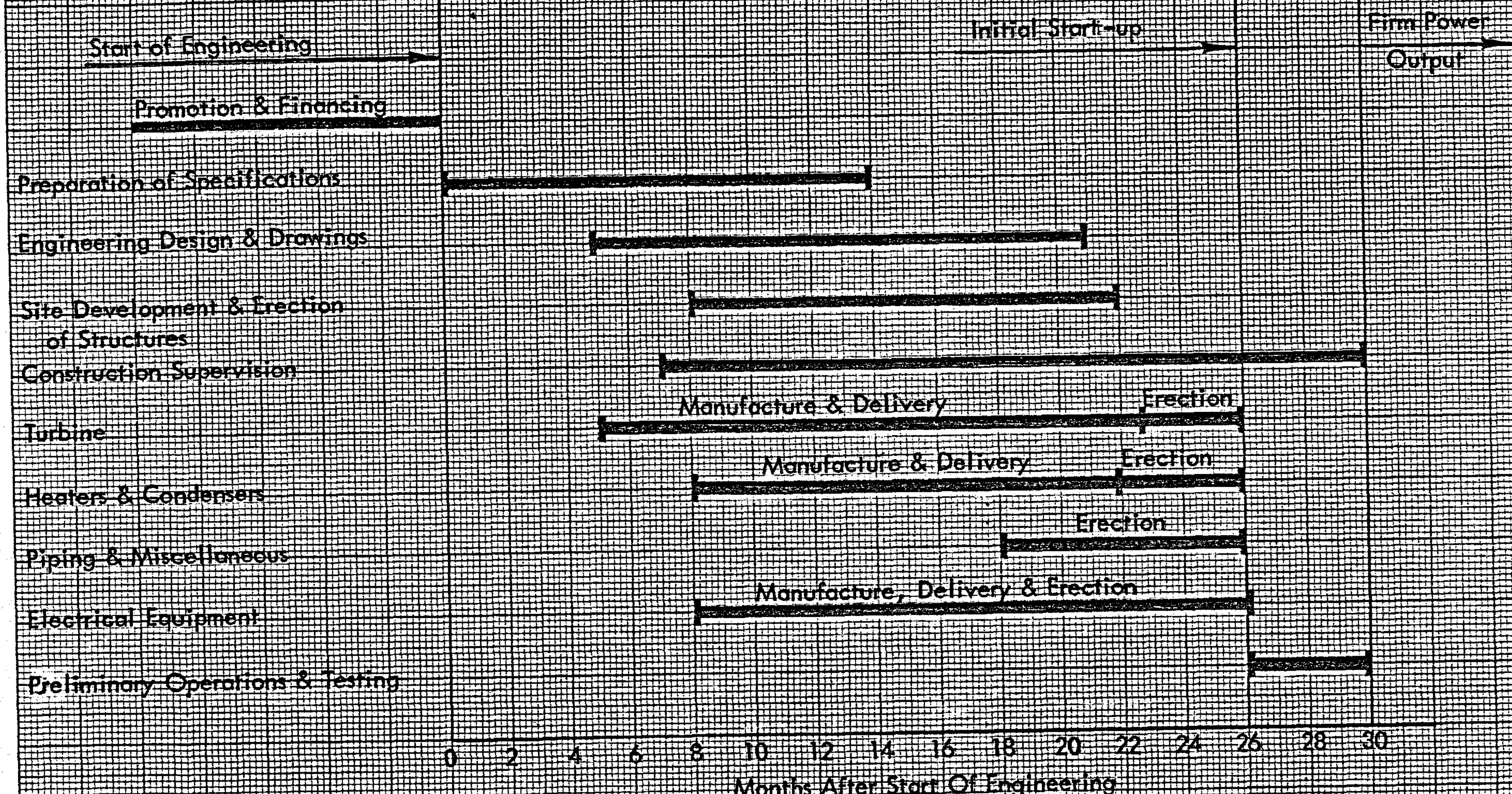
This section presents expected time schedules for the Promotion, Design, Construction and Testing of the two types of geothermal power plants which are the subject of this report. In developing the charts, manufacturer's estimates on delivery of their equipment has been fully considered. The time shown between initial start-up and firm power output might be materially reduced if no start-up troubles developed, but past experience indicates that final checking and adjustments of controls, relays and instruments is a rather indeterminate item. Note that zero time is at the start of engineering.



PROMOTION, DESIGN, CONSTRUCTION & TEST SCHEDULE
DOUBLE FLASH STEAM CYCLE

ROGERS ENGINEERING CO., INC.

RECo No. 1771 JAN. 1962



PROMOTION, DESIGN, CONSTRUCTION & TEST SCHEDULE
CLOSED POWER FLUID CYCLE

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